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(54) An opto-electronic method for determining by length-measurement the quality of cultured fish and a device for implementing the method

(57) Fish is sorted according to quality by the fish 11 being caused to swim through a translucent canal or tube 1 in which it is subjected to radiation of at least one source of radiation 2. The radiation is detectable by a number of photo-detectors in cameras 20 in a row along the length of the tube 1 and the signals from the respective photo-detectors are fed into a computer where the length of the fish is calculated from the degree of masking of the photo-detectors by the fish. A device for implementing the method comprises a translucent tube 1, at least one source of radiation 2 and a number of photo-detectors arranged along the length of the tube 1. The photo-detectors emit a signal depending on whether a fish 11 is present in the tube 1 between a photo-detector (6) and the source of light 2. Each photo detector is arranged in a camera 20, and in front of the photo-detector there is arranged a cylinder lens (8 Figure 2) with its longitudinal axis oriented perpendicular to the longitudinal axis of the tube 1. An ultrasound probe 13 is preferably arranged in the tube 1 to form a visual/digitalized image of the fish 11 internally.

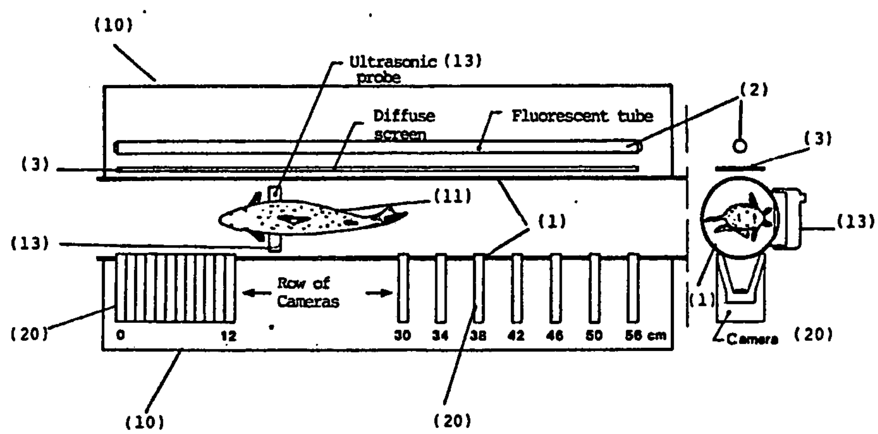

FIGURE 3

The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

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A METHOD FOR DETERMINING THE QUALITY OF CULTURED FISH AND A DEVICE FOR IMPLEMENTING THE METHOD.

The present invention concerns a method and a device for determining the quality of live cultured fish. Determination of quality is here taken to mean determining the size and sex of the fish and its degree of sexual maturity. Based on such a determination of quality, the fish can be graded according to demands and desires.

Fish culture has gradually become a very important activity, not only in Norway but also in a number of other countries around the world. While production in 1971 of salmon and rainbow trout in Norway amounted to 531 tons, by 1984 it had increased to 25806 tons at a first-hand value of a little below 1 billion Norwegian kroner. Prognoses for 1986 and 1987 are 46000 and 61000 tons respectively. Moreover, aquaculture is an area which is given priority by the authorities on the background of the special favourable conditions prevailing in Norway.

Because of the heavy growth of the fish culture industry and the positive prospects for aquaculture in general, the authorities consider this area to be of prime importance for investment. The growing signifance of fish farming in Norway as well as in other countries also means that it becomes ever more important to simplify and automate the production process.

Quality determination and sorting of fish according to size or in connection with sexual maturity is a vital process, to the fish as well as to the crew. Sorting by size is done in order to reduce the density in the seines/dip nets as the fish grows or in order to partition off the fish by size in connection with harvesting. Some fish grow more rapidly than others, and there are many considerations which warrant that small and large fish should be partitioned off from each other, counted and placed in separate dip nets. In terms of feeding techniques it is desirable to have fish all of approximately the same size in one dip net. If there are great variations in the sizes of the fish, there is, moreover, a danger of cannibalism, i.e. the largest fish will eat the smallest ones. Sorting by size is done from 2

to 4 times in the course of the 3 years that salmon remain in the sea, and 2 years in the case of the rainbow trout. The salmon generally reaches sexual maturity after 2.5 years, and the rainbow trout after 1.5 years in the sea. A varying number of male salmon and male trout, however, reach sexual maturity after 1.5 and 0.5 years in the sea, respectively. The growth is halted for a considerable period of time when sexual maturity is reached, and a large percentage of the fish die following spawning or emptying (stroking). There is, consequently, considerable financial gains to be derived from identifying and harvesting sexually mature fish before the growth is halted and the quality of their meat deteriorates. Besides, the parent fish should be sorted out. This entails sorting in June-July of salmon and in October-Novewmber of trout which have been in the sea for 1.5 years or longer and 0.5 years and longer, respectively. The weight (whole) of salmon and rainbow trout at the time of sorting will be seen from table 1.

TABLE 1: Summer weights of salmon and rainbow trout after a varying number of years in the sea.

NO. OF YEARS IN THE SEA		WHOLE WEIGHT (Kg)	
Salmon	Rainbow Trout	Salmon	Rainbow Trout
1	0.5	1 - 3	0.5 - 2
1.5 - 2.5		5	
2	1.5	3 - 8	1 - 6
3	2.5	5 - 15	4 - 12

In female salmon, a slight swollenness of the anus is the only outward sign of sexual maturity. The changes in the anal region occur from mid May and require close inspection by an experienced and practised person. This means that the fish must be netted and subjected to an intimate examination. Even after such an inspection, there is a large percentage of female salmon in which the sexual maturity was incorrectly assessed. Change of colour from shiny silvery to yellowish brown is a very clear indication of sexual maturity. However, this does not take place until August-September and at a time when the growth has stopped and the meat quality declined. In the male fish, the onset of sexual maturity will result in the lower jaw acquiring the shape of a

hook, and the skin growing darker. Figure 1 shows the location of and the names of the internal and external organs of the fish, as well as the anatomical changes which take place in connection with the sexual maturing.
Sorting out of sexually mature fish in fish farms in Norway as well as abroad is done by means of landing nets and a subjective inspection of each single fish. The fish is then distributed in various dip nets according to the sorting result. There are, however, several disadvantages in such a method. Firstly, a considerable number of fish will be incorrectly sorted because the criteria for sexual maturity are imprecise. Secondly, it is an extremely work-consuming and heavy operation to lift many thousand fish in the weight range from 1 to 10 kg with a landing net. It is thus a matter of lifting abt. 30 000 fish annually in a normal Norwegian cultured fish farm if the sorting is to be performed conscientiously. The third and perhaps the most important drawback is, however, that the method subjects the fish to great stress. In general a considerable percentage of the fish will die as a result of stress or the ring effects of stress.

In spite of the drawbacks inherent in this method, nobody has ever before succeeded in replacing this manual system by something better. In the book "Akvakultur" ("Aquaculture") (Oscar Ingebrighsen, Publishers: NKS-Forlaget, 1982) which was published in 1982 and contains an updated explanation of the problems involved in culturing salmon and trout, it is stated expressly that the sorting of fish with a view to sexual maturity could only be done in a visual inspection as described.

It is thus an intention of the present invention to provide a method and a device for determination of the quality of cultured fish in which the above mentioned disadvantages are avoided.

In the novel method, there is less contact with the fish so that it is subjected to less stress. In accordance with the present method, the fish are caused to swim one by one in a tube in which the fish passes certain detectors which form the basis for sorting the fish according to quality.

A possible solution is to use a visible light to provide a profile image of the fish. The profile image of the fish will change with the sexual maturing process, because of the changes in the volume of the roe bag and the string of milt. The deviation of the profile image from a standard of not being sexually mature might be calculated and provide a probability value for the sexual maturity. It has proved, however, that the profile image does not change rapidly enough, and the method cannot therefore be used for sorting with a view to sexual maturity in June-July when this sorting must be done. Nevertheless, it has turned out, surprisingly, that other sources of radiation may be utilized, particularly ultrasound and the result may be shown as a screen image in the usual way. As will be known, such techniques are utilized in human medicine for foetus diagnoses, but it was entirely unexpected to the experts that the same technique might be used to determine sexual maturity in fish.

When determining the sexual maturity in fish it is necessary to make the fish pass through a tube one by one. Initially, it was assumed that salmon and rainbow trout would swim counter to the current in a stream of water, but this has not proven true, and it has been shown that salmon and rainbow trout will swin into a tube which is placed in the dip net at a downward slope if the fish density in the dip net becomes too high. If, therefore, the fish density in a dip net is increased by the seine being pulled together, the fish will try to escape through a tube if given a chance. For the further examination of the fish it is important to be able to freeze a sectioned image of the fish at abt. 1/4 of its length, taken from the tip of its nose. In order to do this, it must be possible to determine the position of the fish, and it is also necessary to procure information about the entire length of the fish. It is therefore desirable to build a system to measure the length of the fish and its position in the passage tube.

Knowledge of the length of each individual fish is in itself valuable information. Precise formulas have been established for the calculation of the weight of a fish from its length, both in salmon and trout (Gjerde and Gjedrem 1984). Even if it was decided to perform the ultrasound diagnosis without freezing the image, knowledge of the size of the individual fish will open up several possibilities.

When a dip net is being filled, such a method will provide a possibility for an exact description of the stock. It will provide information on the total weight of the fish and on the distribution by weight of the fish. Combined with active gates for the sorting of the fish, the method provides the possibility of sorting fish of different sizes to different dip nets. Such sorting is, as mentioned above, desirable for several reasons.

The invention will be described below with reference to the enclosed drawings in which

fig. 1 shows the arrangement of light source and photo detector

fig. 2 shows a "camera" with cylinder lenses

fig. 3 shows a trial box for the determination of the length of the fish and the formation of an ultrasound image, and

fig 4 shows an ultrasound image of a female fish.

Fig. 1 shows a conveniently arranged light source 2 and a photo detector (6). A standard fluorescent tube (2) driven by a high frequency power supply lights up a diffusing glass plate 3. That part of the light which radiates vertically out from the diffusing plate (3) will penetrate the tube 1 of glass or clear plastics through which tube the fish is conducted. The combination of the shape of the tube and the presence of water will cause the combination to serve as a lens at the focus of which is arranged a photo detector (6). Only the hatched parts (5) of the water in the tube will serve as optically active elements. The edge flaws of the lens are thus eliminated, and the liquid-filled tube 1 will serve as a comparatively ideal lens. All parts of the fish which are present within the square (4) in the centre, will contribute to weaken the intensity of light which falls on the photo detector (6).

In fig. 2 is shown how a photo detector (6) is arranged in a specially designed "camera" 20 fitted with cylinder lenses (8) which cause the photo detector (6) to see only a narrow slice of the detection area 4. The camera 20 is equipped with an electronic unit (9) which digitalizes the signal from the photo detector (6) so that the following signals emanate: "fish" or "no fish". In order to further direct the light from the detection area (4) the camera is equipped with vertical non-reflecting sandblasted aluminium sheets (7). These sheets also serve to shield against el-

trical interference. The signals from each of the cameras are fed into a micro computer which is not shown, in which the signals are processed to calculate the length of the fish. A number of such cameras (20) is arranged in rows along the length of the tube (1). The number of such cameras is decisive for the resolution capacity of the system.

Fig. 3 shows the entire system of lenses built inside a watertight box (10) around the tube (1) in which cultured fish swim. Below the tube (1) is also arranged an ultrasound probe (13) which will provide a visual image of the internal organs of the fish. Such an image of the internal organs of the fish is used in determining the sex of the fish, and its degree of sexual maturity, the row of cameras (20) determines its length and position

As will be seen from figure 3, the cameras (20) are arranged in 2 "banks" of which one "bank" contains 12 cameras spaced at intervals of 1 cm, and the other "bank" contains 7 cameras (20) at intervals of 4 cm for the first 6 cameras (20) of the bank.

The first 12 cameras serve for "fine"-observations while the cameras of the other "bank" serve to indicate when the tail fin leaves the field of vision of one of the cameras (20) at the same time as the nose of the fish is recorded by one of the cameras in the first bank. In the image shown, the fish tail is leaving the field of vision of the camera 30 cm distant, while the camera 11 cm distant records the nose. The length of the fish is thus approx. 30 cm less 11 cm = 19 cm.

The system is connected to a micro computer, not shown, which calculates the length of the fish and emits a signal for the control of gates, not shown, and for statistical processing of the results. With the arrangement shown it has been possible to determine the position of the nose and the tail of the fish with a repeatability of approx. 2 mm.

In fig. 4 is shown an ultrasound sectional image of a female salmon with roe. The sectional image was made at abt. 5 cm rearwards of the breast fin. The abdomen of the salmon is turned upwards. An experienced operator would easily be able to identify

two roe bags on either side of the abdominal cavity. The liver can be seen as a dark shadow in the top right-hand area and the stomach and the intestinal system are trapped between the two roe bags. The system works in the following manner: the fish is lured or pressed in a gentle and unstressing fashion to swim into the tube (1) where it is exposed to ultrasound, for instance from a tomograph (13) of the type "PICKER LS 7000" which has a linear scanner with a width of 104 mm. The present method is not restricted to the use of one particular type of tomograph (13), and it is to be expected that by and by, ultrasound apparatus will be developed which will be even better suited for this purpose. Tomographs for medical use often have sector scanners, and these provide a sector shaped section. This is an advantage when used on humans, because it is then easier to form images of tissue underneath the pelvis and other hard parts of the skeleton which obstruct the ray of light. This is of no significance in the determination of the quality of fish, and for such a purpose a linear scanner would seem to be the best suited as it provides better resolution at greater depths. The ultrasound image is being shown continuously on a screen. The size/appearance of the roe bag or the milt will then be evaluated by a person who, through a simple system of valves, will be able to guide the fish to the correct dip net.

The position and the length of the fish in the tube (1) in which it travels, are determined optically, as shown in fig. 3. The light from the light source (2) passes the diffuse screen (3) and falls on to the photo detector (6) located in each of the cameras in the row of cameras, when no fish is present between the light source and the individual cameras. As shown in fig. 3, the cameras at a distance of approx. 11 to 30 cm will record the presence of fish, and beacuse the distance between each camera (20) is known, it will be possible to determine the length of the fish, as described above.

As mentioned previously, the fish will move down into a tube when the dip net becomes too tight, and consequently the measuring equipment must be submerged in water. It is important to its reliability that the volume of the device is as small as possible for reasons of buoyancy, subjection to currents and other interfering elements. A system in which the fish is conducted through

the tube (1) placed in the water-tight box (10) has proved to be reliable and compact, among other things also because the tube (1) with its contained water is used as a "lens" of comparatively short focal distance, which makes it possible to place the respective photo detectors (6) at a short distance from the tube (1). It is self-evident that the lighting technique and location of cameras selected may vary with varying tube diameters, and with the choice of suitable light source such as fluorescent tube with or without diffusing screen or light emitting diodes etc.

Information about the length of the fish and its position may be used in a separate distribution of the fish according to size, but is also necessary in an optimal system for determination of quality with a view to sexual maturity based on ultrasound. The system may be developed further in that an evaluation of the screen image, following digitalization, may be done by computer so that the system becomes independent of the operator and the computer may control a system of valves which guides the fish to the various dip nets. Although the device employed in the implementation of the present method is shown as one unit, it may also be practical to split the system into two units, viz., one in which the length of the fish is determined, and one subsequent unit where the sex determination is made. In particular when the ultrasound image is evaluated visually, it will be an advantage if the fish which are not sexually mature, as warranted by their size, are made to by-pass the ultrasound device or to inactivate it so that the operator will have fewer fish to evaluate. This would for instance be possible if, on the basis of the length of the fish observed, the computer is made to control a gate so that the fish will either pass through the ultrasound device or by-pass it, based on an observed signal for the length of the fish.

CLAIMS

1. A method of determining the quality of fish comprising causing the fish to swim through a translucent canal or a tube in which it is subjected to radiation of at least one radiation source, said radiation being detectable by a number of photo detectors arranged in a row along the length of the tube, and feeding the signals from the respective photodetectors into a computer where the length of the fish is calculated.

2. A method according to claim 1, wherein the fish is also caused to swim past an ultrasound probe which provides a visual or digitalized image section of the fish internally, said image forming the basis for the determination of sex and sexual maturity.

3. A method according to claim 1 or 2, wherein the image section through the fish is made at a predetermined distance from the nasal region of the fish, the said distance and position being calculated on the basis of the size of the fish.

4. A method according to any one of claims 1 to 3, wherein the fish, following the determination of size and sexual maturity, is guided to the appropriate dip nets by means of gate arrangements which are controlled manually or automatically on the basis of the determination of size/sex.

5. A device determining the quality of fish, comprising a translucent tube, at least one source of radiation, and several photo detectors arranged along the length of the tube, said photo detectors emitting a signal depending on whether there is a fish in the tube between a photo detector and the light source.

6. A device according to claim 5, wherein, in front of every photo detector there is a cylinder lens whose longitudinal axis is oriented perpendicular to the longitudinal axis of the tube.

7. A device according to claim 5, wherein each photo detector is separated off by means of horizontal partitions which touch the outside of the tube on the opposite side to the source of radiation.

8. A device according to claim 7, wherein said horizontal partitions are non-reflecting.

9. A device according to any one of claims 5 to 8, wherein an ultrasound probe is arranged in the tube in order to form a visual/digitalized image of the fish interior.

10. A method for determining the quality of fish, substantially as hereinbefore described with reference to the accompanying drawings.

11. A device for determining the quality of fish, substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawings.

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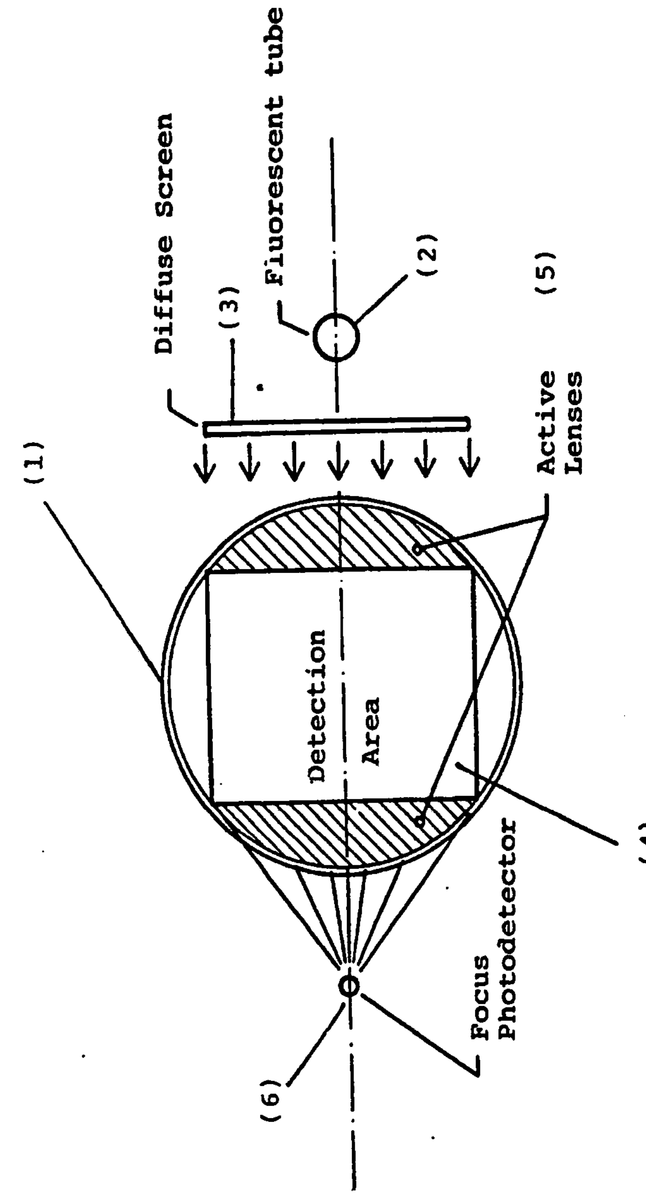

Fluorescent tube
Diffuse Screen
(1)
(2)
(3)
(4)
(5)
(6)
Active Lenses
Detection Area
Focus Photodetector

FIGURE 1

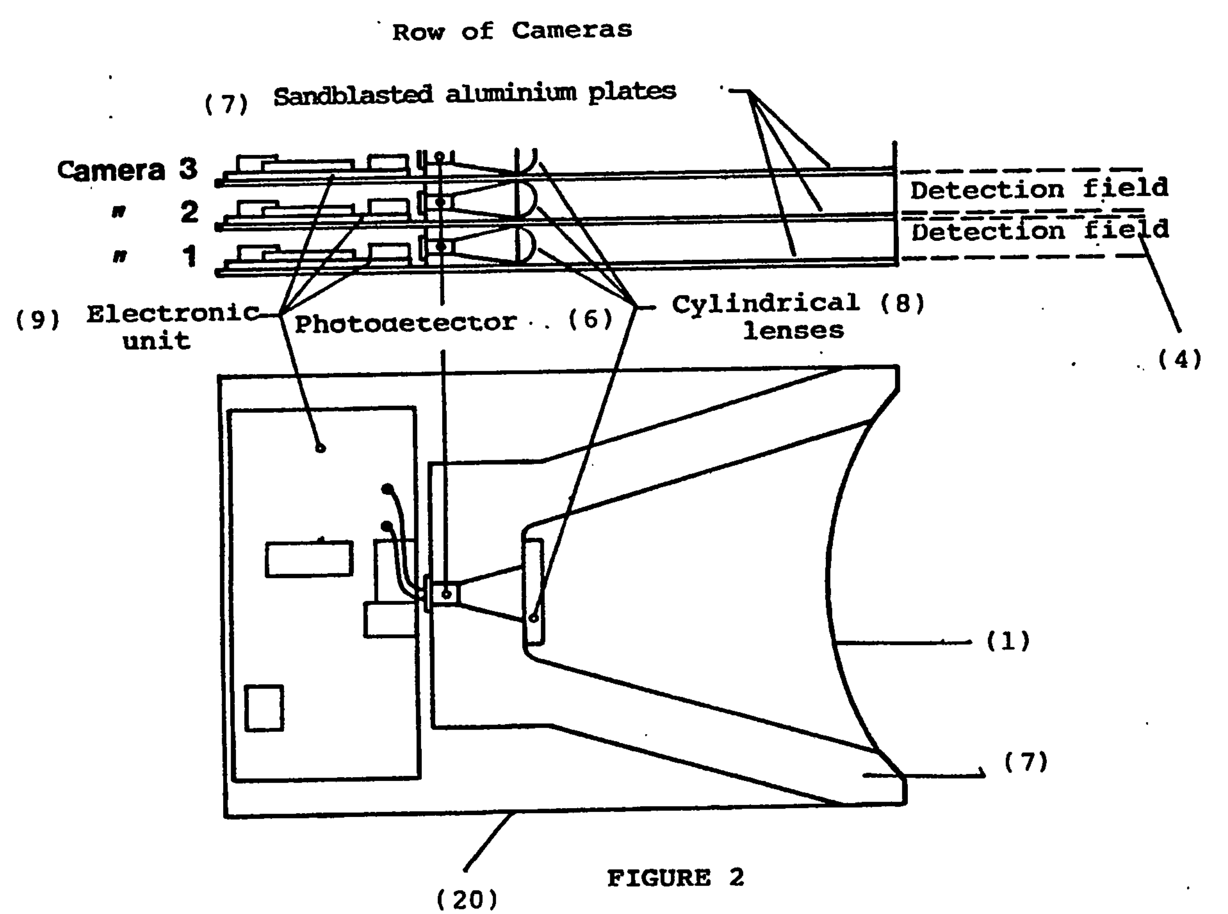
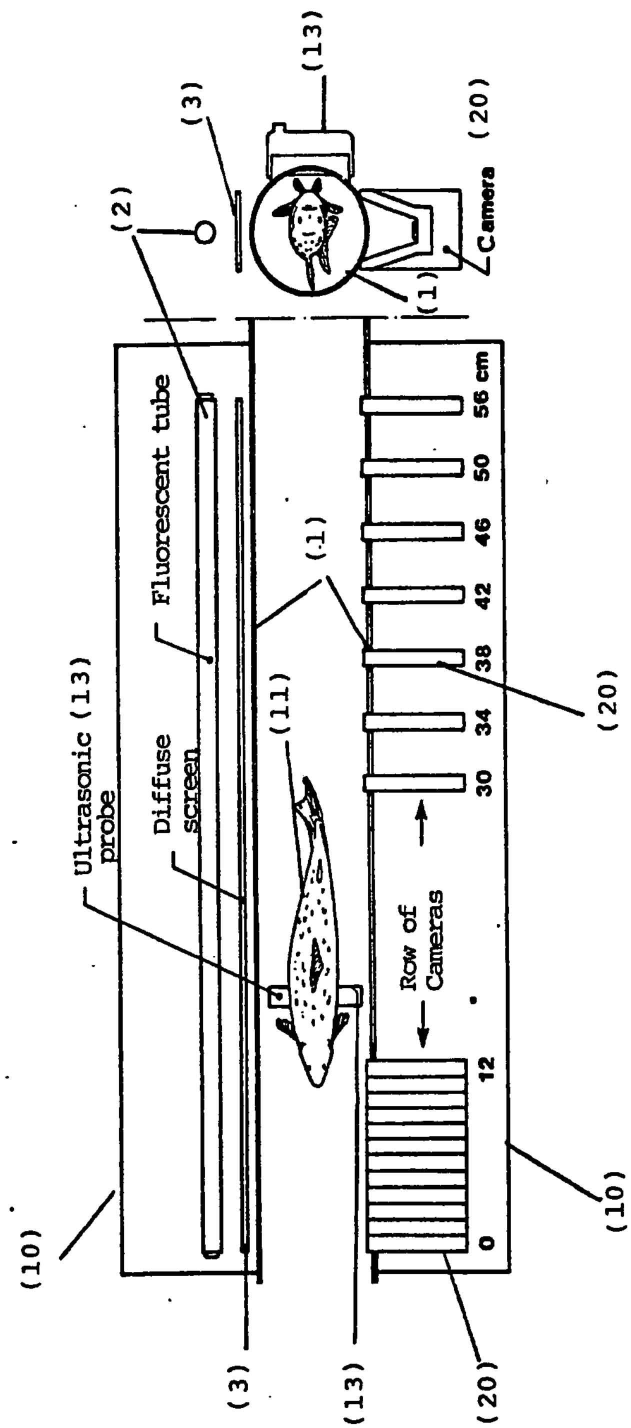

Row of Cameras
(7) Sandblasted aluminium plates
Camera 3
" 2
" 1
Detection field
Detection field
(9) Electronic unit
Photodetector
(6)
Cylindrical (8) lenses
(4)
(1)
(7)
(20)

FIGURE 2



(13)
(3)
(20)
(2)
Camera
(1)
Fluorescent tube
(1)
(11)
Ultrasonic (13) probe
Diffuse screen
Row of Cameras
56 cm
50
46
42
38
34
30
12
0
(20)
(10)
(10)
(3)
(13)
(20)

FIGURE 3

FIGUR 4